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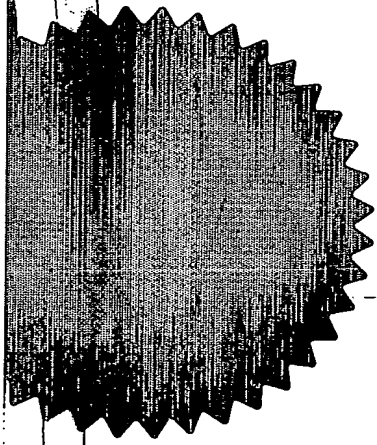
Application No.   S2003/0281

Date of Filing   14 April 2003

Applicant   INTUNE TECHNOLOGIES LIMITED, an Irish company of 9c Beckett Way, Park West Business Park, Nangor Road, Dublin 12, Ireland.

Dated this 22 day of April 2004.

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Form No.1

REQUEST FOR THE GRANT OF A PATENT

Patents Act, 1992

The Applicant(s) named herein hereby request(s)

the grant of a patent under Part II of the Act

☒ the grant of a short term patent under Part III of the Act on the basis of the information furnished hereunder

1. <u>Applicant(s)</u>

<u>Name:</u> **INTUNE TECHNOLOGIES LIMITED**

<u>Address:</u> **9c Beckett Way, Park West Business Park, Nangor Road, Dublin 12, Ireland**

<u>Description/Nationality:</u> **an Irish Company**

2. <u>Title of Invention:</u>

METHOD AND APPARATUS FOR CONTINUOUS SWEEPING OF A TUNABLE LASER

3. <u>Declaration of Priority on basis of previously filed application(s) for same invention (Sections 25 & 26)</u>

<u>Previous Filing Date</u>   <u>Country in or for which filed</u>   <u>Filing No.</u>

4. <u>Identification of Inventor(s):</u>

<u>Name(s) of person(s) believed by applicants to be the inventor(s) address:</u>

5. <u>Statement of right to be granted a patent (Section 17(2) (b))</u>

Date of assignment from inventors:

6. <u>Items accompanying this Request - tick as appropriate</u>

    (i)   ☒ prescribed filing fee

    (ii)   ☒ specification containing a description and claims
            specification containing a description only
            ☒ Drawings to be referred to in description or claims

    (iii)   An abstract

    (iv)   Copy of previous application(s) whose priority is claimed

(v)   Translation of previous application whose priority is claimed

(vi)   ☒ Authorisation of Agent (this may be given at 8 below if this request is
         signed by the applicant(s))

7. Divisional Application(s)

The following is applicable to the present application which is made under Section 24 -

    Earlier Application No:
    Filing Date:

8. Agent

The following is authorised to act as agent in all proceedings connected with the obtaining of a
patent to which this request relates and in relation to any patent granted -

    <u>Name</u>   <u>Address</u>

    TOMKINS & CO.   5 Dartmouth Road,
                                     Dublin 6.

9. Address for Service (if different from that at 8)

TOMKINS & CO., at their address as recorded for the time being in the Register of
Patent Agents.

Signed   Name(s):
                by:
                Capacity (if the applicant is a body corporate):

<u>Date:</u> 14 April 2003

AUTO8934

Title

Method and Apparatus for continuous sweeping of a tunable laser

Field of the Invention

5   This invention relates to tunable lasers and the requirement to sweep a range of wavelengths in a continuous manner. This invention specifically relates to a method to stitch two or more continuous tuning regions of the laser together. Within the present specification
10   the term "continuous sweeping" means that there are no discernable glitches or jumps in the output frequency of the device outside of the smooth sweep across the wavelength range of interest.

Background to the Invention

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Multi section laser diodes are well known in the art and can be switched between different wavelengths. Typically, the diode is calibrated at manufacture to determine the correct controls that should be applied so as to effect
20   the desired output frequencies from the laser.

One of the first known multi-section laser diodes is a three-section tuneable distributed Bragg reflector (DBR) laser. Other types of multi-section diode lasers are the
25   sampled grating DBR (SG-DBR), the superstructure sampled DBR (SSG-DBR) and the grating assisted coupler with rear sampled or superstructure grating reflector (GCSR). There are also other laser types such as the External Cavity Laser (ECL) and gas lasers. A review of such lasers is
30   given in *Jens Buus, Markus Christian Amann, "Tuneable Laser Diodes" Artect House, 1998 and "Widely Tuneable Semiconductor Lasers" ECOC'00. Beck Mason.*

Figure 1 is a schematic drawing of a DBR 10. The laser
35   comprises of a Bragg reflector sections 2 with a gain or

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active section 6 and phase section 4. An anti-reflection coating 9 is sometimes provided on the front and/or rear facets of the chip to avoid facet modes. The Bragg reflector takes the form of Bragg gratings 5. The pitch

5   of the gratings of the Bragg reflector varies slightly to provide a Bragg mode which moves in frequency through varying the current supplied to this sections. The optical path length of the cavity can also be tuned with the phase section, for example by refractive index

10   changes induced by varying the carrier density in this section. A more detailed description of the DBR and other tuneable multi-section diode lasers can be found elsewhere *Jens Buus, Markus Christian Amann, "Tuneable Laser Diodes" Artect House, 1998.*

15

As detailed above such tunable semiconductor lasers contain sections where current is injected to control the output frequency, mode purity and power characteristics of the device. Various applications in

20   telecommunications/sensor fields require the laser to sweep across a particular wavelength range in as continuous a manner as possible. Moreover many applications require that the range in wavelength that is to be swept to be quite large, up to 80nm and higher.

25   However, certain types of tunable lasers have only a set of narrow ranges of wavelengths over which they can be continuously tuned. These individual continuously tunable regions when put end to end will cover the full sweep range of interest with some overlap.

30

It is desirable therefore to have a scheme by which each of these continuous regions can be seamlessly stitched together to give the appearance of continuous tuning.

Object of the invention

The object of the present invention is to provide a method for stitching together continuous regions of a multi-section tunable laser in an efficient and accurate manner.

Summary of the Invention

Accordingly the present invention provides a method adapted to identify for a predetermined wavelength the end of a first continuously tunable region within the range of operation of the laser and thereafter to once again identify this same wavelength at the beginning of a second continuously tunable region with high accuracy.

Desirably the first and second continuously tunable regions are adjacent or overlap with one another. A control signal can then be provided to highlight the times when continuous tuning operation is being performed. By limiting a suitable receiver to only make measurements when the control signal is asserted, the method of the present invention provides for a high level of confidence in the continuous tuning behaviour in the measurements. The methodology and technique is generic to all types of laser devices and therefore can be applied to several different types of tunable laser such as ECL, DBR, SG-DBR, GCSR etc.

Desirably, once the first and second continuously tunable regions are identified, a method of stitching them together so as to form a usable tuning data set may be provided.

According to first embodiment of the present invention a method of providing a set of continuous tuning regions

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from a discontinuously tuned laser is provided, the
method comprising the steps of:
    providing a wavelength reference having at least
first and second resonance peaks,

5   sweeping the laser across a pre-determined
wavelength range of the wavelength reference, and
    defining, within the laser sweep, one or more
regions of continuous tuning operation of the laser, each
of the regions corresponding to a response of the laser

10 between adjacent resonance peaks of the wavelength
reference.

Desirably, the one or more regions of continuous tuning
operation are adjacent to one another. Alternatively, the

15 one or more regions of continuous tuning operation are
displaced from one another across the pre-determined
wavelength range. In such an alternative the regions may
be chosen randomly within the pre-determined wavelength
range.

20

The method may further comprise the step of:
    stitching two or more regions to one another so as
to form a usable tuning data set.

25 Such stitching the two or more regions to one another is
desirably effected by:
        a. creating a lookup table of regions that have
            continuous tuning over a first frequency region
            with a frequency overlap on either side with the

30   previous and next continuous tuning regions,
        b. asserting a control signal to denote a continuous
            region when the first resonance peak is detected,
        c. de-asserting the control signal and jumping to
            the next continuous tuning region when the next

35   resonance peak is found within this continuous
            tuning region, and

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d. repeating the above steps (b-c) until a
            sufficient range of wavelength has been swept.

    The regions of continuing tuning operation of the laser
5   are desirably defined by:
            calibrating the laser so as to provide a range of
                currents with no mode jumps,
            selecting continuous regions with a first frequency
                overlap that have a resonance peak in the
10   wavelength response from their beginnings and
                ends, and
            setting the currents whilst sweeping through those
                wavelengths so as to provide a smoothly
                transitioning wavelength sweep.
15

    The step of setting the currents is typically provided by
    one or more of the following:
            filtering,
            shaping.
20

    In preferred embodiments the method may include the
    additional step of assigning a frequency (F_{meas}) or
    wavelength (λ_{meas}) value to discrete points within the
    continuous region of operation of the laser device, the
25 value being assigned by:
            measuring the time from the resonance peak at the
                beginning of the sweep to the measurement instant
                (T_{meas}),
            measuring the time required to sweep between
30   adjacent resonance peaks ($T_{segment}$), and
            calculating the value by extracting a value for T_{meas}
                from $T_{segment}$

    For application of a frequency value and using an etalon
35 as a wavelength reference the method typically includes

                                5

the step of calculating the frequency using the equation:

$$F_{meas} = FSR_{Etalon} * \frac{Tmeas}{Tsegment} + F_{SegmentStart} \; ,$$

where FSR_{Etalon} is the free spectral range of the
reference etalon and $F_{SegmentStart}$ is the absolute
frequency of the first resonant etalon peak in the
segment.

The laser device may be used as a reference source for a
second device. Such an application may use the regions of
continuous tuning operation to define the spectral
characteristics of a second laser device, or to provide
an optical spectrum analyser.

The wavelength reference is desirably provided by one or
more of the following:

a fabry perot etalon,

a gas cell,

fabry bragg grating,

notch filter,

a reflective fabry perot etalon, and

optical filter.

Any portion of the resonance peak may used to determine
the location of the resonance peak.

The invention additionally provides an optical
arrangement adapted to provide a set of continuous tuning
regions from a discontinuously tuned laser, the
arrangement comprising:

a wavelength reference having at least first and
second resonance peaks associated therewith,

a tunable laser,

means for sweeping the laser across a pre-determined
wavelength range of the wavelength reference, and

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means for defining, within the laser sweep, one or more regions of continuous tuning operation of the laser, each of the regions corresponding to a response of the laser between adjacent resonance peaks of the wavelength

5   reference.

These and other features of the present invention will be better understood with reference to the following

10   drawings.

Brief Description of the drawings

Figure 1 shows a schematic of a Distributed Bragg
15   Reflector Laser diode.
Figure 2 shows a schematic of an embodiment of the system in a typical application.
Figure 3 shows how a continuous sweep may be obtained from a mode plane.
20   Figure 4 is an example of the output of the high finesse etalon in one of the continuous sweep regions of the laser.
Figure 5 is an example of the spectral characteristics of a fabry-perot filter as used in the methodology of the
25   present invention.
Figure 6 is a plot of frequency vs. time for a system utilising the method of the present invention.
Figure 7 is a schematic of a second application of the methodology of the present invention.
30   ## Detailed Description of the Drawings

The invention will now be described with reference to exemplary embodiments thereof and it will be appreciated that it is not intended to limit the application or
35   methodology to any specific example. The techniques used by the method of the present invention are specifically

provided to enable the formation of a continuous sweep from a discontinuously tuned laser. A continuous sweep is taken to be one which has no discernibly or substantial glitches in frequency along its length, only a smooth transition across the full wavelength range.

The methodology of the present invention will now be described with reference to a three section DBR device, and it will be appreciated from a person skilled in the art that this is only exemplary of the type of device that may be used with the method of the present invention. It will be further appreciated that the technique and methodology herein described is a generic technique being applicable to all narrow and widely tunable lasers such as the SG-DBR, SSG-DBR, DBR and GCSR types.

Figure 2 shows a typical embodiment of the system for a typical application, the system shown enabling the spectral characterisation of the device under test. A tunable laser and control electronics 300 provide the optical output where the output wavelength and power of the laser are controlled by the electronics. The optical power from the laser is passed through a 3-way splitter 310. Part of the light goes to a wavelength reference 340, a direct power measurement 350 and to a device under test (DUT) 320. Three receivers are provided (370) to monitor the wavelength reference power, direct power and the DUT power. These are typically measured with photo- detectors 331, a, b, c and a trans-impedance amplifier 332 a, b, c and the voltages are passed back to the laser and control electronics 300. Connector blocks or interface units 390 are also provided to enable the removable coupling of the DUT, one unit coupling it to the 3-way splitter and the second to the corresponding receiver 360 for the DUT. In operation such an embodiment

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of the invention provides for the analysis of the
spectrum of the device under test by comparison with the
control laser/wavelength reference combination.

5   This application to an accurate wavelength spectral
characterisation is only one exemplary embodiment of the
invention. Other embodiments may include the use of the
methodology within an interrogators or optical spectrum
analyser.
10

To achieve the high accuracies required a wavelength
reference is required that can be used in conjunction
with the laser. In this exemplary technique, a Fabry
Perot etalon is used but it will be appreciated that
15   other references can be used which provide a similar
characteristic. The Fabry Perot (FP) filter that is used
desirably has a high Finesse (>30). A high finesse filter
will be less dependent on output power variations of the
tunable laser. The spectral characteristics of such a
20   filter is shown in Figure 4. It will be apparent, as
shown in Figure 5, that such a filter has at least two
resonance peaks, each being associated with a high level
of transmissivity at specific frequencies. Between these
peaks the filter exhibits low levels of transmissivity.
25   This means that there is a large extinction ratio between
the resonance peaks and away from the resonance peak.
This also means that the spectral width of the filter is
small (<5pm). As the laser sweeps across the wavelength
ranges, when the wavelength coincides with a resonance
30   peak a response is obtained on a receiving photodiode. As
the Free Spectral Range (FSR and the start frequency of
the FP filter is well know and an approximate frequency
of the laser is known (from, for example, an initial
calibration of the laser) when the laser wavelength is at
35   a resonance of the FP filter the wavelength of the laser
can be determined very accurately (to much better than

0.1pm resolutions). This enables high accuracy of the
laser source to be determined at the wavelength reference
peaks as the wavelength at each peak is known accurately.
and the laser is calibrated so that in-between each
5   resonance the wavelength tuning is linear in time,
therefore the wavelength at any point between two such
resonance's can be referenced from the time taken for the
laser from the first resonance to the second resonance,
i.e.

10

λ_1= Wavelength of the first resonance

λ_1+FSR= wavelength of the second resonance

T= time to sweep from λ_1 to the second resonance peak

K= time to reach a wavelength between the two resonance's

15   λ= wavelength at time K

Therefore

λ=K/T*FSR+λ_1

Another example of a suitable wavelength reference would
20   be a gas cell. It will be understood that a gas cell will
provide a multitude of reference peaks to reference the
tunable laser while sweeping, and while these peaks are
not typically displaced regularly from one another, the
use of such a cell is advantageous in that it is less
25   susceptible to pressure or temperature effects and can
therefore serve as a more accurate reference than for
example the fabry-perot etalon. In a further example an
etalon could be referenced to a gas cell, so as to
provide an absolute reference and then the substantially
30   regular intervals between the resonance peaks of the
fabry-perot could be used in combination with the tunable
laser in the method of the invention.

As can be seen from Figure 3 a continuous tuning region
35   is obtained by finding a line which crosses no mode

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boundaries 210. This is shown as a black line 200 in a phase, bragg plane, where the degree of shading denotes the output wavelength of the laser. By choosing a region to sweep the currents that do not cross a mode jump of

5 the laser continuous tuning is achieved. This can be accomplished in a number of ways as reported in "*Complete Wavelength Control of a GCSR Laser over EDFA Band*" IEEE LEOS'99, San Francisco, Nov'99, T. Farrell et al. This results in a set of continuous tuning regions and a

10 subset of these is taken which cover the wavelength range of interest.

Figure 4 shows the current on the phase section of the laser vs. the output frequency of the laser. It will be

15 appreciated that similar plots may be obtained for the other sections of the laser which must be controlled in a similar manner to achieve the continuous tuning. Specifically, a similar control current function is required for the Bragg section in the case of a 3 section

20 DBR laser, and of the front and back reflector sections of the SG-DBR laser. If there is a requirement to keep the output power of the laser constant during the sweep the gain section can also be controlled to compensate. Use of a Digital to Analog Converter (DAC) which will

25 step the currents at the required resolution, can be used to implement this, as will be appreciated by those skilled in the art. Also an electronic filter can be used to smooth the currents to achieve smooth continuous tuning of the laser source.

30

Once a series of these continuous sweeps has been identified, a set of continuous regions can be selected each of which overlap by a predetermined frequency, typically 10 GHz, and each of which starts and end 10 GHz

35 from one of the peaks of the high finesse etalon. Each continuous tuning range of the laser will sweep the

wavelength of the laser across two different peaks, so
that all the continuous tuning ranges cover all the gaps
between reference peaks in the wavelength range of
interest. The laser may then be swept through each of

5   these continuous regions. In operation, the wavelength
reference of the filter is used to identify the regions
of the sweep that are used. This is performed by using a
control signal which is asserted when the sweep hits a
first wavelength reference and de-asserted when the sweep

10   hits a second reference. A control signal can be
generated by use of a threshold operation on the response
of the wavelength reference. When the light level is
above a threshold value, this signifies that the
wavelength of the laser is at the wavelength reference

15   wavelength of that peak. This can be implemented with the
use of a comparator and some simple logic elements. A
reference is identified when the optical power received
through the reference is above a threshold. This is
explained in more detail in the following sections.

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When sweeping the laser across one continuous tuning
region the sweep will cross two wavelength reference
peaks, equivalent to the two peaks of the etalon. Upon
the wavelength of the laser hitting the first wavelength

25   reference peak the control signal is asserted. This means
that the laser is now sweeping linearly across a
wavelength range between two reference wavelengths. Upon
hitting the second etalon peak in this continuous sweep
it de-asserts the control signal associated with the

30   continuous regions of the sweep and starts sweeping along
the beginning of the overlapping region of the next
continuous region. Then the next continuous wavelength
tuning region is used. During this sweep it once again
detects the peak of the wavelength reference it will know

35   it is at exactly the same frequency as the end of the
last sweep and can reassert the control signal thereby

providing seamless continuity in the tuning with no gaps or overlaps in wavelength in the measurements.

Figure 6 shows a plot of Frequency vs. Time for the system with measurements only being taken when the control signal is asserted. The gaps in the response allow for the sweeping of the laser in regions where the control signal is not asserted and therefore not used. It will be appreciated that although there are breaks in between each of the sets of continuous regions that these breaks represent time delays and that the end point of one set and the start point of a second set are at the same wavelength (as could be seen from the intercept of both points against the Y-axis, line 430). It will be also appreciated that time can be allowed for the laser to reach thermal equilibrium between each continuously tunable region.

As such it will be appreciated that Figure 6 represents a reference spectrum for the tunable laser 300, which can then be used for examination of the characteristics of the DUT 325. A linear continuous curve may be formed from extrapolation of the data provided in Figure 6.

The wavelength reference used allows exact wavelength calibration of the sweep. This is significant as the output wavelength of the laser can change due to degradation, ambient temperature etc. An important property of this system is that as the laser degrades etc. the absolute wavelength of the laser can vary but the linearity of the sweep is constant. The rate of change of wavelength of the sweep can also vary but by the novel implementation defined in this patent the calculation of the wavelength at any time is not affected.

A second embodiment can be described once again with reference to a three section DBR device.

Again as can be seen from Figure 3 a continuous tuning
5   region is obtained by finding a line that crosses no mode boundaries. This can be accomplished in a number of ways such as in *"Complete Wavelength Control of a GCSR Laser over EDFA Band" IEEE LEOS'99, San Francisco, Nov'99, T. Farrell et al.* The simplest is to locate each of the mode
10   boundaries using some appropriate type of filter and compute the equation of the line between them.

Once a series of these continuous sweeps has been identified, a set of continuous regions can be selected
15   each of which overlap by a predetermined frequency such as 10 GHz and each of which starts and ends 10 GHz from one of the peaks of the high finesse etalon. The laser then sweeps through each of these continuous regions. Upon hitting the second etalon peak in a particular
20   continuous sweep it de-asserts the control signal associated with the continuous regions of the sweep and starts sweeping along the beginning of the overlapping region of the next continuous region. When during this sweep it once again detects the peak of the etalon it
25   will know it is at exactly the same frequency and can reassert the control signal thereby providing seamless continuity in the tuning with no gaps or overlaps in wavelength in the measurements.

30   The accuracy and performance of the tunable laser is dependent on the accuracy of the calibration. By calibrating the laser to high accuracy and achieving a linear wavelength sweep with respect to time this novel technique can deliver high speed and high accuracy not
35   available with existing techniques technology.

If a sweeper with sub 0.1 pm accuracy is required over a
typical 40nm sweep range this results in 40,000 points
that have to be set on the laser. For each of these
points multiple currents have to be controlled to ensure
5   linear tuning, good SMSR, line width and constant output
power. This can result in a large amount of data, i.e.
for a SG-DBR laser where 4 laser sections are controlled
(Front reflector, Back reflector, Phase and Gain or SOA)
the number of bytes of data in a lookup table is 40,000
10   different set points multiplied by 4 controlled sections
by 2 bytes to store the set value = 40,000 x 4 x 2 = 320
Kbytes. While this is straightforward for a PC in an
actual instrument this will rapidly become the bottleneck
and the sweep speed will suffer. For example for a sweep
15   speed of 100ms, the data needs to be retrieved at
3.2Mbytes/sec processed and set to the laser. The
methodology of the present invention may be extended to
provide a method of approximating the tuning of each
section that allows for data minimisation and speed of
20   sweep.

Figure 4 shows the characteristic tuning of a segment of
the laser. It will be noted that the other sections of
the laser must be controlled to achieve this type of
25   tuning. To get a good approximation of this curve a
complex equation is required to fit, an example of which
will be given as below.

An approximation that works well over most of the tuning
30   rate is
Y=a+b/(c-x) where y is the output frequency of the laser
and x is the phase current.

As this function requires a divide to calculate this
35   takes significant time and reduces the overall speed of
sweep possible. Use of a polynomial approximation can

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provide sufficient accuracy with enough coefficients to a given or required wavelength accuracy. Also reducing the segment size can greatly reduce the error of a low order polynomial fit. The advantage of using a polynomial fit

5   is that this can be implemented by using a set of difference equations and result in a set of additions to be performed rather than time consuming multiplies or divides.

10 By using a polynomial which can be calculated as a set of additions this means that the speed of the calculations can be performed quickly and not effect the speed of the sweep. This means that the sweep speed can be limited by the physical properties of the laser instead of the

15. supporting electronics.

It will be appreciated that the present invention provides a method for establishing a continuous tuning set from a discontinuous laser. Such a method of

20 operating a tunable laser, as provided by the present invention provides a high accuracy sweeping tunable source by means of a wavelength reference. The method desirably provides for a calibration of a tunable laser in a manner that provides for continuously tunable

25 segments between each known wavelength from the wavelength reference. As will be understood from the above mentioned exemplary embodiment, any gaps between known wavelengths of the wavelength reference are traversed by a single segment, and desirably each of the

30 continuously tunable segments overlaps with the adjacent segments.

By calibrating the tunable laser in a manner wherein the wavelength tuning is constant with time while in

35 operation, the wavelength of the laser at any time can be

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calculated from the wavelength references at the time for the laser to tune between them

In a further embodiment, as shown in Figure 7, the DUT can be an optical source and the system can be configured to measure the wavelength of the optical source as a wavelength meter, or perform as an optical spectrum analyser. This involves a heterodyne detection method 371 where the optical light from the tunable laser and the optical device under test are mixed (in coupler 311) and a beat signal generated. This beat signal is at a frequency of the difference between the two optical signals. By low pass filtering the photodiode detector a beat will only be present on the receiver when the frequency difference between the two optical signals in less than the bandwidth of the low pass filter. The heterodyne receiver performs the following actions

1. AC couple the photodiode response

2. Low Pass the photodiode response

3. Rectify the low passed output

4. Low pass the rectified output or integrate and dump. With use of the correct bandwidths when the optical wavelength of the DUT and the tunable laser are within the required wavelength of each other a signal is received on the heterodyne receiver. As the wavelength of the tunable laser is known the wavelength of the DUT can be measured.

It will be appreciated that the present invention provides a method that enables the use of resonance peaks in a wavelength reference to define regions of continuous operation of a discontinuous laser device. By subdividing the operating region of the laser device into segments or regions of continuous operation the present invention provides for continuous operating regions in an extended sweep of the laser device. This has application in a

number of different fields for example as an optical
spectrum analyser or the like.

<u>Claims</u>

1. A method of providing a set of continuous tuning
regions from a discontinuously tuned laser, the method
comprising the steps of:
    providing a wavelength reference having at least
first and second resonance peaks,
    sweeping the laser across a pre-determined
wavelength range of the wavelength reference, and
    defining, within the laser sweep, one or more
regions of continuous tuning operation of the laser, each
of the regions corresponding to a response of the laser
between adjacent resonance peaks of the wavelength
reference.

2. The method as claimed in claim 1 wherein the one or
more regions of continuous tuning operation are adjacent
to one another.

3. The method as claimed in claim 1 wherein the one or
more regions of continuous tuning operation are displaced
from one another across the pre-determined wavelength
range.

4. The method as claimed in claim 1 further comprising
the step of:
    stitching two or more regions to one another so as
to form a usable tuning data set.

5. The method as claimed in claim 4 wherein the step of
stitching the two or more regions to one another is
effected by:
    a. creating a lookup table of regions that have
        continuous tuning over a first frequency region

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with a frequency overlap on either side with the
previous and next continuous tuning regions,

    b. asserting a control signal to denote a continuous
region when the first resonance peak is detected,

    c. de-asserting the control signal and jumping to
the next continuous tuning region when the next
resonance peak is found within this continuous
tuning region, and

    d. repeating the above steps (b-c) until a
sufficient range of wavelength has been swept.

6.   The method as claimed in any preceding claim wherein
the regions of continuing tuning operation of the laser
are defined by:

    calibrating the laser so as to provide a range of
currents with no mode jumps,

    selecting continuous regions with a first frequency
overlap that have a resonance peak in the
wavelength response from their beginnings and
ends, and

    setting the currents whilst sweeping through those
wavelengths so as to provide a smoothly
transitioning wavelength sweep.

7.   The method as claimed in claim 6 wherein the step of
setting the currents is provided by one or more of the
following:

    filtering,

    shaping.

8.   The method as claimed in any preceding claim further
comprising the step of assigning a frequency (F_{meas}) or
wavelength (λ_{meas}) value to discrete points within the
continuous region of operation of the laser device, the
value being assigned by:

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measuring the time from the resonance peak at the
beginning of the sweep to the measurement instant
(T_{meas}),

measuring the time required to sweep between

5   adjacent resonance peaks ($T_{segment}$), and

calculating the value by extracting a value for T_{meas}
from $T_{segment}$

9.   The method as claimed in claim 8 wherein the value

10   is a frequency value (F_{meas}) and the wavelength reference
is an etalon, the frequency being calculated using the
equation:

$$F_{meas} = FSR_{Etalon} * \frac{Tmeas}{Tsegment} + F_{SegmentStart} ,$$

where FSR_{Etalon} is the free spectral range of the

15   reference etalon and $F_{SegmentStart}$ is the absolute

frequency of the first resonant etalon peak in the

segment.

10.   The method as claimed in any preceding claim further

20   including the step of using the laser device as a

reference source for a second device

11.   The method as claimed in any preceding claim further

25   comprising the step of using the regions of continuous
tuning operation to define the spectral characteristics
of a second laser device.

30   12.   The method as claimed in any one of claims 1 to 10
further comprising the step of using the regions of
continuous tuning operation to provide an optical
spectrum analyser.

13.   The method as claimed in any preceding claim wherein
the wavelength reference is provided by one or more of
the following:
     a fabry perot etalon,
5   a gas cell,
     fibre bragg grating,
     notch filter,
     a reflective fabry perot etalon, and
     optical filter.
10

14.   The method as claimed in any preceding claim wherein
any portion of the resonance peak is used to determine
the location of the resonance peak.

15 15. A optical arrangement adapted to provide a set of
continuous tuning regions from a discontinuously tuned
laser, the arrangement comprising:
     a wavelength reference having at least first and
second resonance peaks associated therewith,
20   a tunable laser,
     means for sweeping the laser across a pre-determined
wavelength range of the wavelength reference, and
     means for defining, within the laser sweep, one or
more regions of continuous tuning operation of the laser,
25 each of the regions corresponding to a response of the
laser between adjacent resonance peaks of the wavelength
reference.

16.   A method substantially as hereinbefore described
30 with reference to and/or as illustrated in Figures 1 to 8
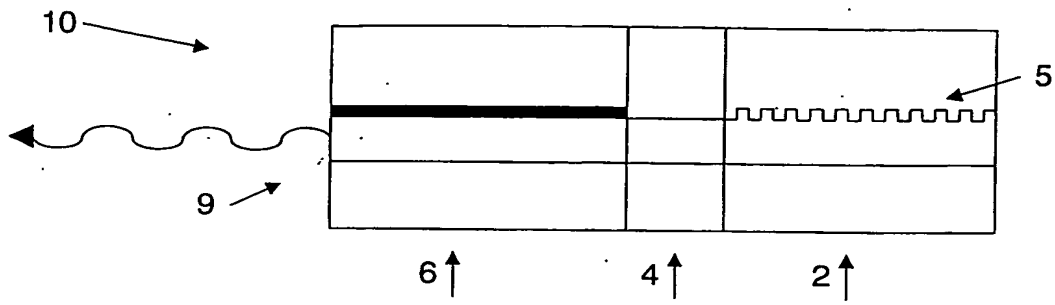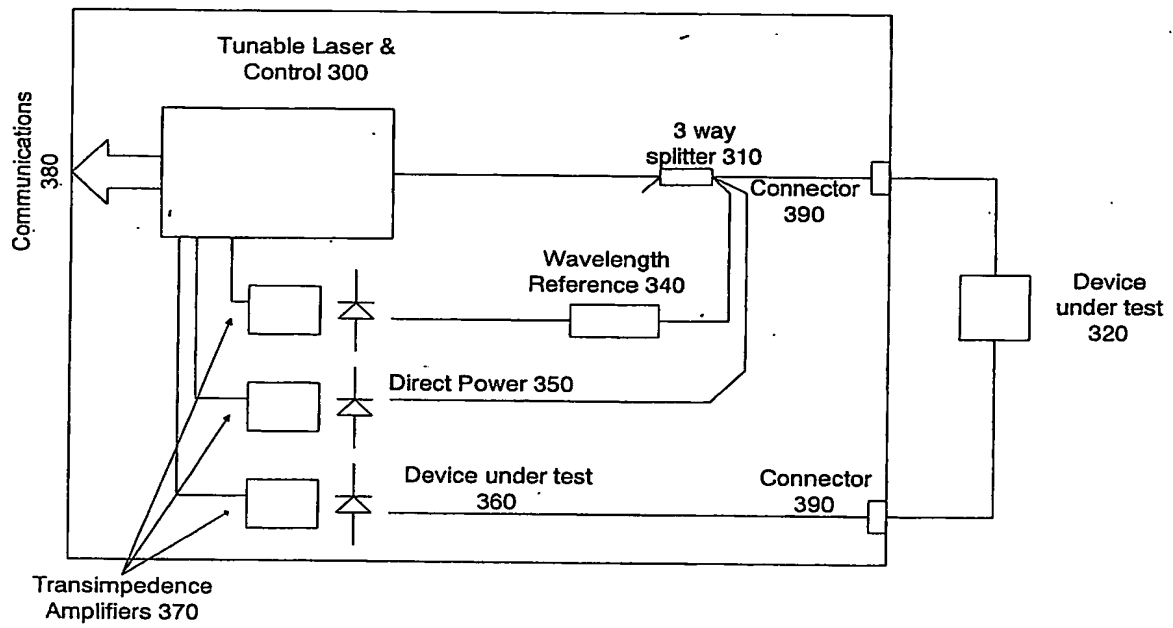of the accompanying drawings.

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Figure 1

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Tunable Laser &
Control 300

3 way
splitter 310

Connector
390

Communications
380

Wavelength
Reference 340

Device
under test
320

Direct Power 350

Device under test
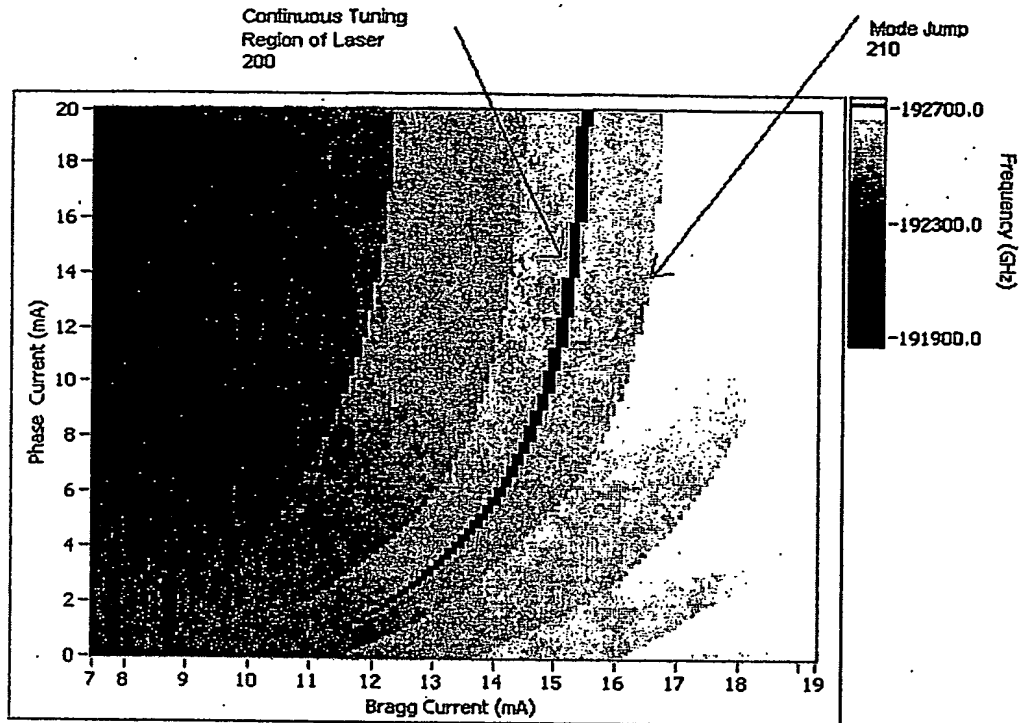360

Connector
390

Transimpedence
Amplifiers 370

Figure 2
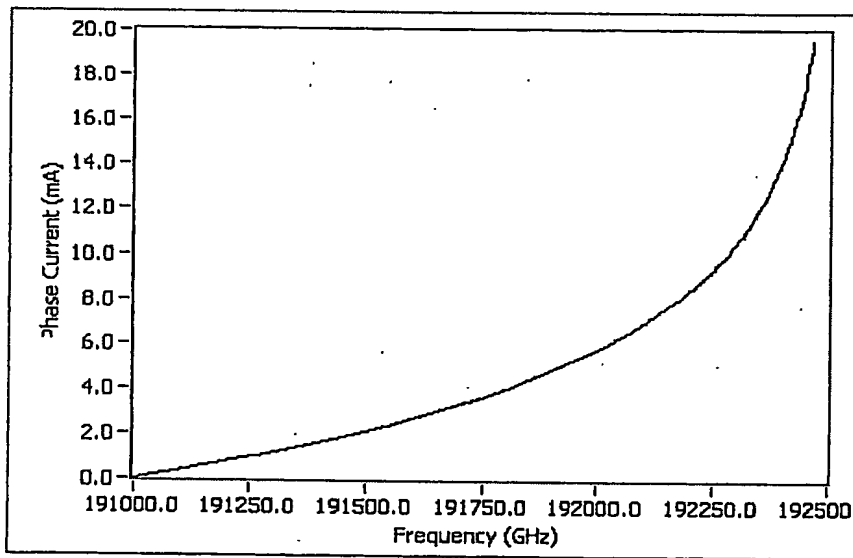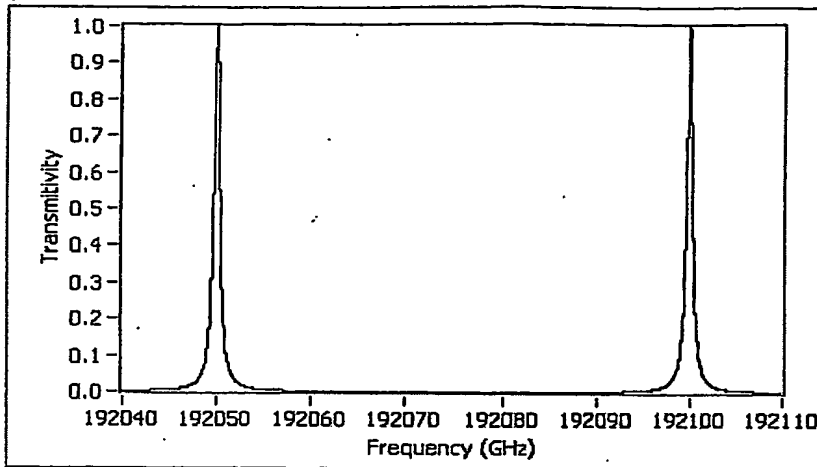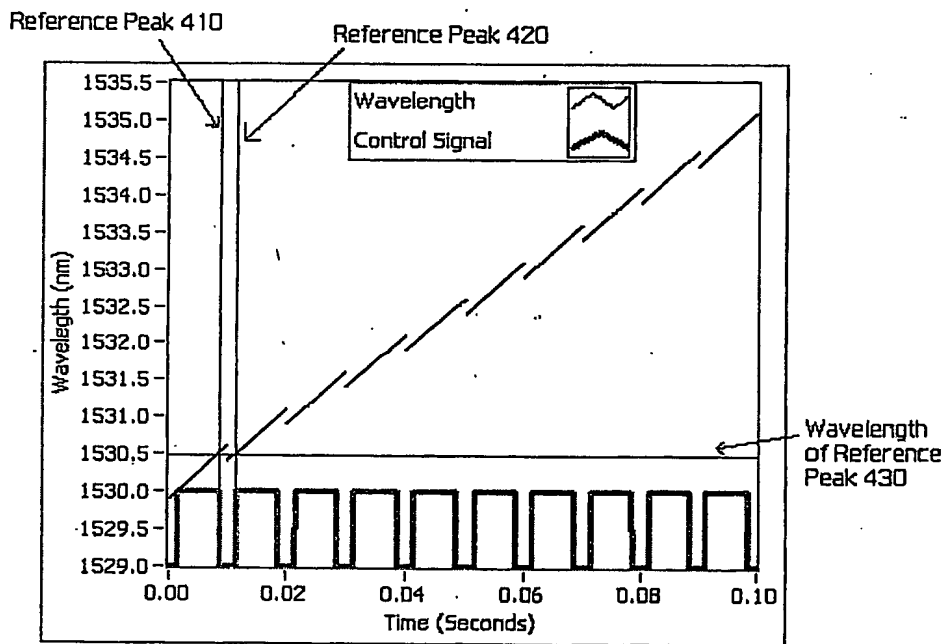
Figure 3
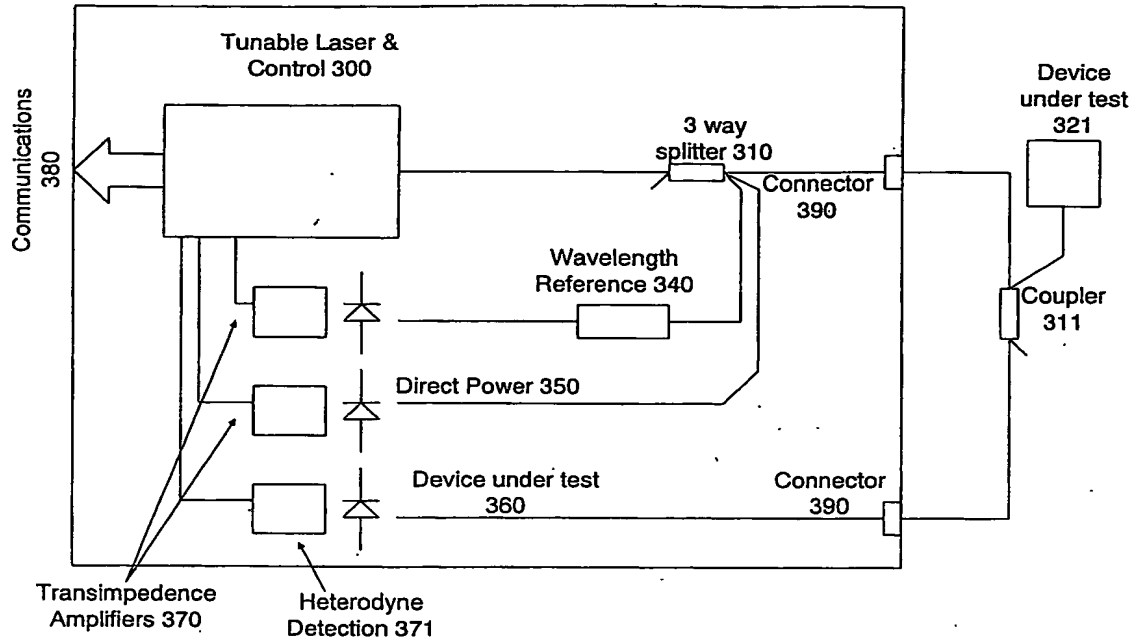

5   Figure 4

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Figure 5

Figure 6

Figure 7

5   *spec1212rety0696*